REMARKS

The amendment to claims 1, 11, 12 and 17 of 0.55 $\leqq$ Cr wt%/C wt% $\leqq$ 1.2 is supported by the paragraph bridging pages 17 and 18 and the first full paragraph on page 20 of the present specification. When the C content is 0.55 wt%, the Cr content is 0.3 wt% or more; and when the C content is 1.5 wt% the Cr content is 1.8 wt% or less. Therefore, the following equation is obtained: 0.55 wt% x C wt% $\leqq$ Cr content $\leqq$ 1.2 x C wt% (0.55 $\leqq$ Cr wt%/C wt% $\leqq$ 1.2).

In the above formula, the constant 0.55 is obtained by 0.3/0.55 and the constant 1.2 is obtained by 1.8/1.5.

The amendment to claim 1 adding the terminology of "Cr solid-dissolved" is supported in the specification on page 11, line 21.

Claims 1, 9, 10, 11, 12 and 17 were rejected under 35 USC 112, second paragraph, for the reasons set forth in item nos. 5 to 9 on pages 3 to 4 of the Office Action.

Claims 1, 9, 10, 11, 12, and 17 were amended to avoid the grounds for the 35 USC 112, second paragraph rejection set forth in item nos. 6 and 7 on page 3 of the Office Action.

Item no. 9 on page 4 of the Office Action refers to claim 10. Claim 10 recites "...the relationship between a DI value in

inches indicating the hardenability of a martensite phase and a gear module M, wherein M is a value obtained by pitch circle diameter divided by the number of teeth...." The terminology set forth in the preceding sentence is discussed in the sentence bridging pages 27 and 28 of the specification. Enclosed are copies of the following publications which discuss the DI value and hardenability: "Fundamentals of Heat Treating: Ideal Diameter" (1 sheet); "Steel Terminology" (2 sheets); and Mike Meier, "The Hardenability of Steel," Department of Chemical Engineering and Materials Science, University of California, Davis, September 13, 2004 (5 sheets).

Therefore, in view of the above amendment to claim 10 and the information provided in the publications identified in the preceding paragraph, withdrawal of the ground of rejection for claim 10 is respectfully requested.

It is respectfully submitted that the present claims comply with all the requirements of 35 USC 102.

Claims 1, 3 to 15, 17 to 20 and 22 were provisionally rejected on the ground of obviousness-type double patenting as being unpatentable over claims of copending application Serial Nos. 10/790,959 and 11/234,959 for the reasons set forth in item no. 3 on pages 2 and 3 of the Office Action.

Copending application Serial Nos. 10/790,959 and 11/234,959 are still being prosecuted. Therefore, until the above-identified application Serial No. 10/790,931, application Serial Nos. 10/790,959 or application Serial No. 11/234,959 are deemed allowable, the double patenting rejection is premature.

Application Serial No. 11/235,425 is a divisional application of the above-identified application Serial No. 10/790,931. **Application Serial No. 11/235,425 was filed pursuant to a Restriction Requirement under 35 USC 121 in the parent application and thus should not have been included in the above double patenting rejection.** Accordingly, it is respectfully requested that the double patenting rejection with respect to application Serial No. 11/235,425 be withdrawn.

Claims 1, 3 to 8 and 17 to 19 were rejected under 35 USC 102 as being anticipated by USP 3,663,314 to Monma et al. for the reasons indicated in item nos. 11 to 19 on pages 4 to 6 of the Office Action.

It was admitted in the Office Action that the Cr concentration in cementite at 2.5 to 10 wt% recited in applicants' claim 1 is not taught by Monma et al.

It was also admitted in the Office Action that the pearlite or retained austenite, as recited in applicants' claims 4 and 5, respectively, are not taught by Monma et al.

It was further admitted in the Office Action that a prior austenite grain size of ASTM 10 or higher recited in applicants' claim 6 is not taught by Monma et al.

It was admitted in the previous Office Action of December 8, 2005 that the prior art does not teach a quenched hardened layer containing 0.1 to 1.5 microns, as recited in applicants' claim 3.

A bearing steel according to Monma et al. is produced such that after the steel is entirely heated in a furnace, a member which has been thoroughly hardened by quenching is tempered. It is considered that based on the following steel composition disclosed in Monma et al. consisting of C: 0.55 to 0.78 wt%, Cr: 0.5 to 2.0 wt%, Mn: 1.00 to 2.00 wt% and Si: 1.0 to 2.0 wt%, that there is a high risk for distortion during quenching or quenching crack.

According to applicants' claims, only a surface layer of a rolling element is case-hardened by induction hardening. More specifically, applicants' present claims relate to a gear member

in which a quench hardened layer is formed along a tooth profile. Monma et al. do not teach or suggest a steel composition suitable for induction hardening or a quench-hardened layer. Monma et al. also do not teach or suggest information relating to how to obtain a martensite structure (carbon concentration).

The following Table 1 shows sample compositions of Monma et al.

1. Alloy Nos. 27 to 32 and 35 to 37 have bearing steel compositions which fall within the compositions set forth in claim 1 of Monma et al.

2. The carbon and the Cr contents in alloy Nos. 12 to 19 and 25 to 37 are within the ranges of carbon and Cr contents in claim 1 of applicants' present claims.

3. In the steel product of applicants' present claims, the Cr content depends on the carbon content in order to ensure that there is a Cr concentration range of 2.5 to 10 wt% in cementite. As discussed above, the paragraph bridging pages 17 and 18 and the first full paragraph on page 20 of the present specification provides a relationship between C (wt%) and Cr (wt%). When the C content is 0.55 wt%, the Cr content is 0.3 wt% or more; and when

the C content is 1.5 wt%, the Cr content is 1.8 wt% or less. Therefore, the following equation is obtained:

0.55 wt% x C wt% $\leqq$ Cr content $\leqq$ 1.2 x C wt%.

In the above formula, the constant 0.55 is obtained by 0.3/0.55, and the constant 1.2 is obtained by 1.8/1.5.

It is clear that none of the alloy Nos. 12 to 19 or 25 to 37 of Monma et al. satisfies the above equation. Since Monma et al. do not teach the appropriate balance between carbon content and chromium content, there is a substantial distinction between applicants' present claims and Monma et al.

Table 1

Alloy compositions in Monma et al. and (% Cr/%C) evaluation

No.	C	Si	Mn	Cr	Cr/C≦1.2
No.1	0.2	0.2	0.22	0.14	0.700
No.2	0.38	0.23	0.26	0.12	0.316
No.3	0.5	0.23	0.3	0.13	0.260
No.4	0.61	0.22	0.29	0.12	0.197
No.5	0.84	0.25	0.21	0.12	0.143
No.6	0.22	0.25	0.3	0.14	0.636
No.7	0.4	0.26	0.43	0.14	0.350
No.8	0.44	0.2	0.34	0.14	0.318
No.9	0.5	0.21	0.35	0.14	0.280
No.10	0.6	0.26	0.44	0.14	0.233
No.11	0.8	0.26	0.44	0.14	0.175
No.12	0.45	0.33	0.39	1.44	3.200
No.13	0.55	0.34	0.41	1.47	2.673
No.14	0.65	0.36	0.38	1.45	2.231
No.15	0.7	0.35	0.38	1.5	2.143
No.16	0.78	0.35	0.38	1.5	1.923
No.17	0.88	0.35	0.41	1.48	1.682
No.18	0.95	0.33	0.39	1.45	1.526
No.19	1.17	0.35	0.42	1.45	1.239
No.20	0.44	0.2	0.34	0.14	0.318
No.21	0.45	0.8	0.4	0.13	0.289
No.22	0.45	0.04	0.38	0.12	0.267
No.23	0.46	1.47	0.38	0.13	0.283
No.24	0.44	1.83	0.3	0.14	0.318
No.25	0.7	0.35	0.38	1.5	2.143
No.26	0.71	0.88	0.41	1.44	2.028
No.27	0.68	1	0.38	1.44	2.118
No.28	0.69	1.2	0.39	1.46	2.116
No.29	0.69	1.5	0.39	1.45	2.101
No.30	0.7	1.67	0.4	1.45	2.071
No.31	0.7	1.8	0.37	1.43	2.043
No.32	0.71	1.99	0.3	1.46	2.056
No.33	0.95	0.25	0.41	1.44	1.516
No.34	0.78	0.22	0.37	1.46	1.872
No.35	0.78	1.52	0.25	1.32	1.692
No.36	0.65	1.63	0.69	1	1.538
No.37	0.55	1.7	0.9	1.6	2.909

Withdrawal of the 35 USC 102 rejection is thus respectfully requested.

Claims 10 to 15, 20 and 22 were rejected under 35 USC 103 as being unpatentable over USP 3,663,314 to Monma et al. in view of US 2002/0029597 to Choe et al. for the reasons indicated in item nos. 21 to 23 on pages 6 to 7 of the Office Action.

USP 3,663,314 to Monma et al. was discussed above.

It was admitted in the Office Action that the prior art does not teach shot peening as a finishing step to produce a residual compressive stress on the surface of the rolling bearing element, as recited in applicants' claims 10 to 15, 20 and 22.

It was further admitted in the Office Action that the prior art does not teach the DI formula recited by applicants' claim 10.

Claims 1, 3 to 15, 17 to 20 and 22 were rejected under 35 USC 103 as being unpatentable over EP 950 723 in view of the English-language abstracts of JP 6-25736 and JP 60-162726 for the reasons stated in item nos. 24 to 33 on pages 7 to 9 of the Office Action.

It was admitted in the Office Action that the prior art does not teach a Cr concentration of 2.5 to 10 wt% in the cementite ((Fe, Cr)3C) as recited in applicants' claim 1.

It was also admitted in the Office Action that the prior art does not teach a prior austenite grain having an ASTM grain size 10.

It was furthermore admitted in the Office Action that the prior art does not teach the DI equation for the gear, as recited in applicants' claim 10.

It was also admitted in the Office Action that the prior art does not teach tempering at 100 to 300°C, as recited in applicants' method claim 17.

Moreover, it was admitted in the Office Action that heating by induction at a rate of 150°C/sec or more is not taught by the prior art.

It is respectfully submitted that none of the cited references teach or suggest the proportion of the C content to the Cr content or the average Cr concentration in the cementite, as recited in applicants' present claims.

Withdrawal of both of the 35 USC 103 rejections is thus respectfully requested.

Reconsideration is requested. Allowance is solicited.

An INFORMATION DISCLOSURE STATEMENT is being filed concomitantly herewith.

If the Examiner has any comments, questions, objections or recommendations, the Examiner is invited to telephone the undersigned at the telephone number given below for prompt action.

Respectfully submitted,

Richard S. Barth
Reg. No. 28,180

Frishauf, Holtz, Goodman
& Chick, P.C.
220 Fifth Avenue, 16th Fl.
New York, NY 10001-7708
Tel. Nos. (212) 319-4900
(212) 319-4551/Ext. 219
Fax No.: (212) 319-5101
E-Mail Address: BARTH@FHGC-LAW.COM
RSB/ddf

Encs.: (1) PETITION FOR EXTENSION OF TIME
(2) a copy of "Fundamentals of Heat Treating: ideal Diameter" (1 sheet)
(3) a copy of "Steel Terminology" (2 sheets)
(4) a copy of Mike Meier, "The Hardenability of Steel," Department of Chemical Engineering and Materials Science, University of California, Davis, September 13, 2004 (5 sheets)
(5) INFORMATION DISCLOSURE STATEMENT

Fundamentals of heat treating: ideal diameter.

A quantitative measure of a steel's hardenability is expressed by its DI, or ideal diameter, value. This abbreviation comes from the French phrase "diametre ideal" and refers to the largest diameter of steel bar that can be quenched to produce 50% martensite in its center (Fig. 1). The quench rate of the bar is assumed to be infinitely fast on the outside; that is, it has sufficient quench severity so the heat removal rate is controlled by the thermal diffusivity of the metal and not the heat transfer rate from the steel to the quenchant. Typically, water or brine provides these infinitely fast quench conditions. The larger the ideal diameter value, the more hardenable is the steel.

[ILLUSTRATION OMITTED]

DI values are an excellent means of comparing the relative hardenability of two materials as well as determining if it is possible to harden a particular cross section (or ruling section) of a given steel. DI values are influenced by the hardenability (chemical composition) of a material, the grain size and the severity of quench. It is important to note that hardness in steel is determined by carbon content while hardenability is determined by the alloy chemistry, which also includes carbon. Elements such as copper and vanadium...

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Steel Terminology

STRAND CASTING (Continuous Casting)-A direct solidification process used to cast molten stee or billets, thereby bypassing the ingot solidification and reheat stages of steel production. In stran steel "melt" is tapped into a ladle in the conventional manner. The liquid steel is then teemed (pou tundish, which acts as a reservoir to provide for a controlled casting rate. The molten steel flows f tundish into the casting machine, where rapid surface solidification begins in the open-ended, wat copper molds. The partially solidified bloom or billet is continuously extracted from the open botto mold. Solidification is completed by further cooling the emerging continuous cast steel. Several st be cast side-by-side or in parallel, depending upon the heat tonnage and section size. Variations composition are minimized due to the rapid solidification rate of the strand cast product.

BLOOM A rectangular product whose width is no more than twice its thickness, and whose area i least 36 square inches. A bloom also may be furnished as either a semi-finished hot rolled produc cast section.

BILLET Either an as-cast section that has not yet been hot worked, or a solid semi-finished rounc that has been hot worked, usually smaller than a bloom section. Also, a general term for wrought stock for forgings, extrusions, or for re-rolling into other products.

MACHINABILITY The relative ease with which a steel may be cut by machine tools. There is no : standard measurement of machinability. It is often expressed by one or more of the following term speed; productivity; tool life; tool wear; part growth; chip formation; surface finish. The main mach operations are turning, parting, milling and drilling. The inherent machinability of steel is related to composition and microstructure.

PICKLING An operation by which surface oxide (high temperature scale) is removed by chemical Sulfuric acid is typically used for carbon and low alloy steels. After the acid bath, the steel is rinse

QUENCHING & TEMPERING A thermal treatment consisting of uniformly heating steel to a pred austenitizing temperature and cooling rapidly in air or liquid medium (usually water or oil) to produ microstructure, usually martensite. As-quenched martensite is characteristically very hard and brit allowed to remain in this highly stressed condition, cracks will tend to form in all but low carbon st been recognized that the optimum combinations of strength and toughness are developed in stee microstructure of martensite has been tempered. To prevent cracking, martensite should be temp immediately after quenching, and at a temperature to produce the hardness desired for service.

HARDENABILITY (Response to Heat Treatment) The physical property of steel which determin of martensitic hardness that can be induced by quenching from temperatures over 1330°F. The c composition and austenitic grain size of the steel completely determine its hardenability, with alm elements making varying degrees of contribution.

Hardenability should not be confused with hardness per se or with maximum hardness. Whereas quenched surface hardness of steel is primarily dependent upon carbon content and cooling rate, which a certain hardness level is maintained with a given quenching condition is a measure of har

JOMINY END QUENCH HARDENABILITY TEST A laboratory heat treating procedure for determ hardenability of steel by reproducing a range of specific quenching rates on a single test specime performed by heating a standardized test specimen above the upper critical temperature, then qu the hot specimen in a fixture so that a column of cold water impinges on the bottom end of the sp test specimen is progressively quenched to room temperature, and the decreasing hardness is m its maximum value (near the quenched end of the specimen) at regularly spaced intervals away fr quenched end. The hardness measurements are plotted as a function of distance away from the end. This plot is known as the steel's hardenability band. The range of cooling rates on a standar specimen has been correlated to bar diameter size for both oil and water quenchants.

DI (Ideal Diameter) The DI is an alternate method for predicting hardenability. DI represents the theoretical bar diameter that will harden at the center with at least 50% martensite, when subjecte "ideal" quench (e.g., Grossman quench severity in which H=infinity).

THE HARDENABILITY OF STEEL

Introduction

Maximum Hardness: Maximum hardness in steels is obtained by producing a fully martensitic structure. This can be done by austenitizing the steel and then quenching it. During the austenitizing treatment all of the carbides dissolve and the ferrite transforms into austenite. Quenching this structure causes the austenite to transform via a shear mechanism into martensite. This transformation is so fast (Martensite needles grow at close to the speed of sound.) that there is no time to the carbon to diffuse out of the martensite grains or to form carbide phases. The martensite, supersaturated with carbon, is very hard and also very brittle.

Carbon, being a very effective solid solution strengthening agent, essentially determines the hardness of the martensite. Cases where a lesser degree of hardening can be attributed to the presence of other alloying elements, but these elements tend to also make it more difficult to obtain a fully martensitic microstructure. So while maximum hardness in a given steel is dependent on our ability to produce a fully martensitic microstructure, the hardness of the martensite is largely determined by its carbon content.

Hardenability: In order to form a fully martensitic structure the steel must be quenched at a rate that is equal to or greater than a critical cooling rate. If the quench is indeed fast enough and the part is thin then one can usually assume that this cooling rate can be achieved through the whole cross-section, producing a fully hardened part. However, this may not be the case for thick sections because the interior cools more slowly than the surface. But if one could modify this steel such that critical cooling rate is lower then thick pieces can be hardened throughout and even thicker pieces can be hardened to a considerable depth. This is of great practical importance not only in terms of our ability to produce a fully hardened part (which will also be fully brittle) but because subsequent tempering will be successful in producing the desired strength and ductility throughout the part. In addition, one could use less severe quenches to avoid problems with warping and cracking.

This ability of a steel to be hardened to a specified depth is called hardenability. In general, the hardenability of a steel is improved through alloying and all alloy additions except cobalt will improve the hardenability of a steel. Coarse grain size and homogeneity of the austenite also improve the hardenability. The reason this is so is not clear but is probably related to the retardation of nucleation and growth of the ferrite, carbide and bainite phases.

Jominy End-Quench: The most direct measure of the hardenability of a steel is the "critical cooling rate". Hardenability is also demonstrated in cases where large part fails to fully harden. One can measure this in terms of the depth of full hardening, the diameter of bar which will just harden to the center and the depth where the microstructure consists of 50% martensite. A more convenient and very widely used method of measuring hardenability is the Jominy end-quench test. (Developed by Jominy and Boegehold in 1939, standardized in ASTM A255.) In this test a 1-inch diameter by 4-inches long bar is austenitized then quickly removed from the furnace and placed in a fixture where a jet of water of specified temperature and pressure impinges on one end of the specimen. Once cool, the specimen is removed, cleaned, a flat is ground along the length of the specimen and then is hardness tested every 0.0625 to 0.25 inches from the quenched end. The result is a plot of

hardness versus distance from the quenched end. This curve is used to compare the hardenabilities of different steels.

Ideal Diameter: The ideal diameter D_I is another measure of the hardenability of steel. It is defined as the diameter of a bar which would contain 50% martensite at its center following a quench in an ideal medium. Clearly, the larger the ideal diameter, the higher the hardenability of the steel. The ideal diameter of a plain carbon steel having a carbon content of 0.4% (1040 steel) and whose ASTM grain size number is 7 is 0.215 inches. Naturally, varying the grain size or changing the concentration of alloying elements will change the ideal diameter. An empirical method of accounting for these effects is utilizes a series of multiplying factors:

$$D_I = D_{I,base} f_{Mn} f_{Si} f_S f_P f_{Cr} \cdots$$

where the base ideal diameter is a function of grain size and carbon content and the multiplying factors f_i are function of composition of element I. The ideal diameter for a 4340 steel (0.8 Cr, 1.75 Ni, 0.25 Mo) is over 6 inches.

The objective of this experiment is the measure the hardenability of several plain carbon and low-alloy steels. The results will be used to explain the influence of alloy composition on the kinetics of martensite formation. They will also be compared to the calculated values of the ideal diameter.

Safety Considerations

This experiment involves heating several steel rods to as high as 875°C, quickly taking them out of the furnace and loading the hot specimens into a quenching fixture and then quenching the specimen. After this the specimens are ground flat along several sides and hardness tested along the length of the specimen. Extreme care should be exercised during the heat treating phase of the experiment as the temperatures are quite high and therefore pose severe burn hazards to personnel and fire hazards to the building. Grinding will be done by technicians in the machine shop so this will not be an issue during this experiment. Hardness testing, however, involves the use of a special fixture and a diamond brale indentor. One should be very careful when using this fixture and the brale indentor so that neither are damaged.

Chemical Hazards

None. No chemicals are used and the specimens are 1-inch diameter rods made from conventional steels.

Physical Hazards

1. The potential for very serious burns exists. Temperatures approaching 900°C are used during these experiments. At these temperatures one can easily be burned while loading and unloading specimens from the furnaces, even if the hot specimens and furnace are not touched. It will be important to wear heat resistant gloves and to use long tongs. One should also take care to prepare a clear area to work, have an emergency procedure in place in case hot specimens are dropped on the floor, etc. It would be a good idea to rehearse the procedures for handling hot specimens.

2. Hardness testing poses very little hazard if proper testing procedures are followed. Using the proper anvil and indentor and a clean specimen will minimize the chance

of damaging the equipment or injuring personnel.

Biohazards

None.

Radiation Hazards

None.

Protective Equipment

Recommended: The use of safety glasses is recommended during the hardness testing phase of the experiment. The use of protective coverings for the floor and counter tops is also recommended.

Required: safety glasses, heat resistant gloves and long tongs for the heat treatment phases of the experiment.

Waste

Used specimens can be recycled as scrap steel.

Materials

The alloys used in this experiment are standard grades of the following steels: 1045, 4140, 4340 and 8620. Several have the same carbon content but have different concentrations of the other alloying elements. The specimens are standard Jominy specimens, 1 inch in diameter and 4 inches long with a flat washer pressed onto one end. (This washer can be removed after quenching.) One the end which has the washer a single letter which identifies the steel by composition has been stamped. During the austenitizing treatment this stamp will probably be lost due to oxidation or carburization. A more substantial marking should be used.

Procedure

1. Preliminary

Obtain a copy of ASTM A255 and read it.

Consult the reference books and databases to find out what the ideal diameters for the steels being tested are.

Calculate the ideal diameters and the Jominy curves for your steels.

List the nominal compositions of each of the alloys. Mark, engrave or notch each specimen so that they can still be identified after having spent an hour or so in the furnace.

2. Prepare the Jominy quench tank

Set up the quench tank over a sink and connect a hose to the faucet. Place a specimen in the quench tank. Open the valve on the quench tank and, using the valve on the faucet, adjust the flow of water so that the height of the column of water is ½-inch above the bottom of the specimen. Close the valve on the quench tank but do not adjust the valve on the faucet.

3. Austenitizing Treatments

Preheat a furnace to 850°C and place the specimens in a container filled with graphite and place this

in the furnace. Allow the specimens to soak at this temperature for one hour.

4. Prepare to quench the specimens
The purpose here is to prepare the work area for handling red-hot steel safely. Start by clearing a path between the furnace and the Jominy quench tank. Next, devise a plan for dealing with accidents such as dropping a hot specimen on the floor. Collect up gloves, tongs and safety equipment that will be used to move the specimens to the quench tank. Decide who will remove the specimen from the furnace and place it in the quenching fixture, who will assist in pushing the specimen through the hole in the quenching fixture (if necessary), who will turn on the water, who will monitor the time it took to start the quench, and who will execute the emergency procedures. Rehearse the procedure several times using a cold specimen.

5. Quench the Specimens
Clear a path between the furnace and Jominy quench tank. Quickly but carefully remove a specimen from the furnace and place it in the quenching fixture and immediately turn on the water using the valve on the quench tank. Continue the quench until the specimen is cool enough to handle using bare hands. Remove the specimen from the fixture and engrave or paint an ID code on it.

6. Hardness test the specimens
Clean the specimens and grind a flat surface 0.015 inches deep along four sides (90° apart) of the specimen. This will have to be done in the machine shop.

Set up a Rockwell-type hardness tester for measuring hardness values on the C scale. Hardness test a couple of test blocks to make sure everything is working properly. Install the Jominy hardness testing fixture.

Take a hardness reading every 1/16 inch from the quenched end of the specimen. After the first ½ inch increase this interval to ⅛ inches and after the first full inch increase the interval to ¼ inches. Repeat this procedure for each of the flats on the specimen and then plot each of the four sets of results on a single graph.

Analysis

1. Compare the results (maximum hardness and the hardenability curves) with published data.
2. Compare the results with the calculated Jominy curves and ideal diameters.
3. Compare the maximum hardnesses obtained for the four alloys.
4. Compare the Jominy curves to the ideal diameters.
5. Discuss the differences in the hardenabilities of the four alloys. You can use depth to obtain a specified hardness value or the inflection point on the curves as your basis for comparison.
6. Discuss the results in terms of composition and the TTT curves.

References and Further Reading

1. E.C. Bain and H.W.Paxton, Alloying Elements in Steel, ASM, Metals Park, OH, 1966.
2. Properties and Selection: Irons and Steels, Metals Handbook, volume 1, 9th edition, ASM,

Metals Park, OH, 1986.

3. Atlas of Isothermal Transformation and Cooling Transformation Diagrams, ed. H.E.Boyer, ASM, Metals Park, OH, 1977.